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Detachment Control Considerations for Divertor Design

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The control of a stable detachment solution that is compatible with both the core and edge may be crucial for the operation of reactor tokamaks in steady-state. In tokamaks there exist various methods of accessing and maintaining detachment, including fuelling, impurity seeding, and varying the heating power of the machine. How detachment is accessed and how its extent from the target (location of the detachment 'front') evolves with changes in those controllers can be significantly dependent on the characteristics of the configuration of the divertor employed.

In this work we introduce and utilize simple models that predict the location of a detachment front in a divertor, and how this location evolves with changes in controllers such as impurity seeding [Cowley C et al. Nuclear Fusion. 2022 Jun 20.] [Lipschultz B et al. Nuclear Fusion. 2016 Apr 8;56(5):056007.]. These simple models can be powerful tools to predict how changes in divertor configuration can affect access to and control over detachment. In this study, the simple model predictions have been compared to SOLPS-ITER simulations of isolated divertors in idealised geometries, including high power reactor-like simulations with artificial neon seeding. Broad agreement is found between the predictions of simple models and SOLPS-ITER, which may allow such models to be used for predicting detachment control in real machines.

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The effects of features such as divertor flux expansion (total and poloidal), connection length, gradients in the total field along a flux tube, neutral baffling and magnetic pitch are analysed both in SOLPS-ITER simulation and simple modelling. An example of such analysis can be seen in the figures above, which show the movement of a detachment front in a straight grid and one which is poloidally flared near the target. The flared grid shows much slower poloidal front movement, and thus better detachment control in the flared region. However, in parallel space the movement of detachment fronts is similar in both grids, which implies that the difference in poloidal front movement is fundamentally due to connection length effects and magnetic pitch.

Along with this poloidally flared grid, many other divertor features are explored, and conclusions are drawn concerning how they can be used to influence the design of divertors for next-generation tokamak reactors and experiments.

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